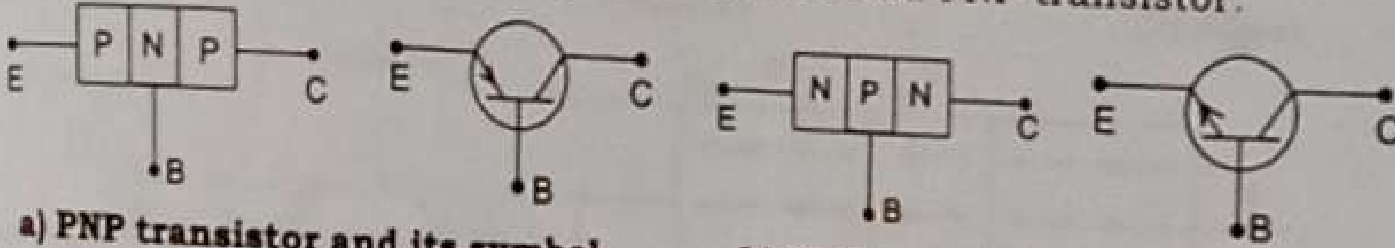
5.10 BIPOLAR JUNCTION TRANSISTORS

5.10.1 Introduction

A bipolar junction transistor is a three layer, two junction and three terminal semiconductor device. Its operation is depends on the interaction of majority and minority carriers. Therefore it is named as bipolar device. The word transistor was derived from the two word combination, (TRANsfer + reSISTOR = TRANSISTOR). Transistor means, signals are transferred from low resistance circuit (input) into high resistance (output) circuit.

Transistor consists of two back to back PN junction joined together to form single piece of semiconductor device. The two junctions gives three region named as emitter, base and collector. There are two types of transistors such as PNP and NPN. The arrow on the emitter specifies whether the transistor is NPN type or PNP type. This arrow also determines the direction of current flow, when the emitter base junction is forward biased. Figure 5.31 shows the circuit representation and symbols of NPN and PNP transistor.



a) PNP transistor and its symbol **b) NPN transistor andits symbol**

Figure 5.31

Emitter

It is more heavily doped than any of other regions because its main function is to supply majority charge carriers (either electrons or holes) to the base. The current through the emitter is emitter current. It is noted as I_E.

Base

Base is the middle section of the transistor. It separates the emitter and collector. It is very lightly doped. It is very thin as compared to either emitter or collector. The current flow through the base section is base current. It is denoted as I_B.

Collector

It forms the right hand side section of the transistor. It is shown in figure 5.31. The main function of the collector is to collect the majority charge carriers coming from the emitter and passing through the base. Generally, collector region is made physically larger than the emitter region, because it has to dissipate much greater power. Collector is a moderately doped. The current flow through the collector section is collector current. It is denoted as I_C.

PNP and NPN transistors

To understand the basic operation of transistor for the following points need to be kept in mind:

1) Emitter section is always to provide charge carriers, therefore, it is always forward biased.

2) First letter of transistor type indicates the polarity of the emitter voltage with respect to base.

3) The main function of collector is to collect or attract those carriers through the base, hence it is always reverse biased.

4) Second letter of transistor type indicates the polarity of collector voltage with respect to the base.

5.10.2 Working of PNP Transistor

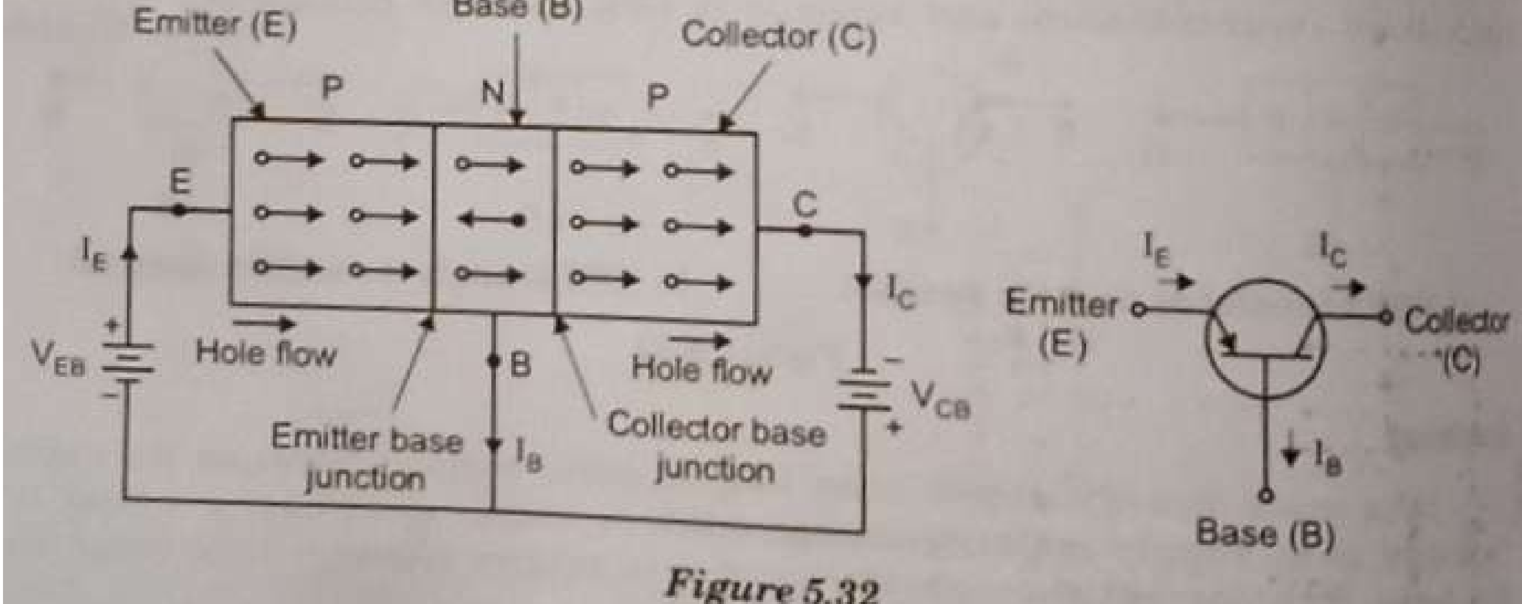


Figure 5.32

Figure 5.32 shows the connection diagram of PNP transistor. In this circuit diagram, the emitter base junction is forward biased (i.e., positive polarity of the battery is connected with 'P' type semiconductor and negative polarity of the battery is connected with 'N' type semiconductor and collector base junction is reverse biased.

The holes in the emiter are repelled by the positive battery terminal towards the PN or emitter junction. Then the potential barrier at emitter junction is reduced as a result of this depletion region disappears, hence holes cross the junction and enter into N-region (base).

This constitutes the emitter current I_E. Because the base region is thin and lightly doped, majority of the holes (about 97.5%) are able to drift across the base without meeting electrons to combine with only 2.5% of the holes recombine with the free electrons or N-region. This constitutes the base current I_B, which is very small. The holes which after crossing the N-P collector junction enter the collector region. They are swept out by the negative collector voltage V_{CB}. This constitutes the collector current I_C.

The following points about transistor circuits are:

1) In a PNP transistor, majority charge carriers are holes.
2) Emitter arrow shows the direction of flow of conventional current. But electrons flows will be in the opposite direction.
3) Emitter base junction is always forward biased and collector base junction is always reverse biased.
4) The collector current is always less than the emitter current because same recombination of holes and electrons takes place.

$$I_C = I_E - I_B$$

$$I_E = I_B + I_C$$

5.10.3 Working of NPN transistor

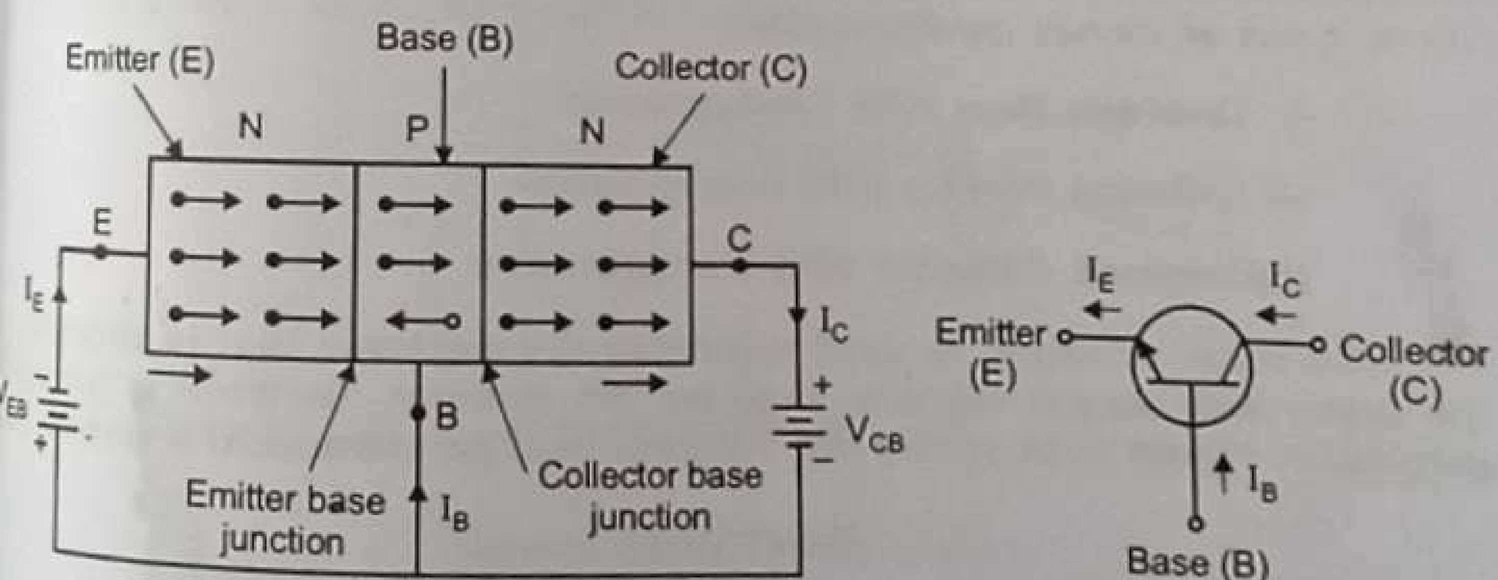


Figure 5.33

Figure 5.33 shows the connection diagram of NPN transistor. In this circuit diagram, the emitter base junction is forward biased (i.e., negative polarity of the battery is connected with 'N' type semiconductor and positive polarity of the battery is connected to with P type semiconductor) and collector base junction is reverse biased.

The electrons in the emitter region are repelled by the negative battery terminal towards the emitter junction. The electron crossover into the P-type base region because potential barrier is reduced due to forward bias and base region is very thin and lightly doped, most of the electrons (about 97.5%) cross over to the collector junction and enter the collector region where they are readily swept up by the positive collector voltage V_{CB}. Only 2.5% of the emitter electrons combine with the holes in the base and are lost as charge carriers.

The following points about transistor circuits are:

1) In a NPN transistor, majority charge carriers are electrons.

2) Emitter arrow shows the direction of flow of conventional current.

3) Collector current I_C is less than emitter current I_E.

The choice of NPN transistor is made more often because majority charge carriers are electrons whose mobility is much more than that of holes.

5.11 TRANSISTOR CIRCUIT CONFIGURATIONS

There are three terminals in a transistor such as emitter base collector. However, when a transistor is to be connected in a circuit, we require four terminals.

Two terminals are used for input connection and other two terminals are used for output connection. This difficulty is overcome by making one terminal common to both input and output circuits. Accordingly, there are three types of circuit configurations.

i) Common Base (CB) Configuration

ii) Common Emitter (CE) Configuration

iii) Common Collector (CC) Configuration

The term 'common' is used to denote the electrode that is common to the input and output circuits, because the common electrode is generally grounded. Figure 5.34 shows the different configuration of NPN transistor

Transistor Configurations

- There are three terminals in a transistor such as emitter, base and collector. However, when a transistor is to be connected in a circuit we require four terminals.

one of the terminals used as common terminal for i/p and o/p Based on that we have different transistor configurations

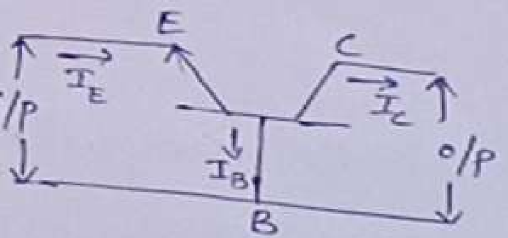
1. Common Base configuration (CB configuration)
2. Common emitter configuration (CE configuration)
3. Common collector configuration (CC configuration)

1. Common Base configuration :-

In a CB configuration, "Base" is the common terminal b/w input and output.

Current Amplification factor:

$$\alpha = \frac{\text{o/p Current}}{\text{i/p Current}} = \frac{I_C}{I_E}$$

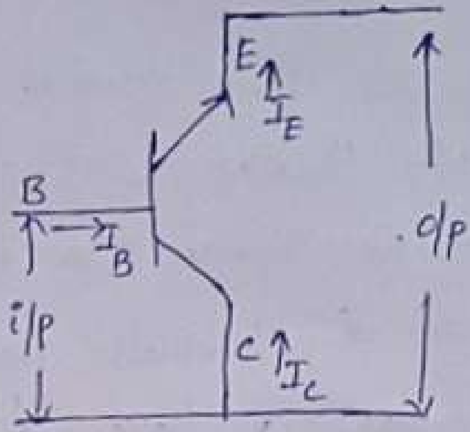


$$I_C \approx I_E$$

$$\alpha \approx 1 \ (0.95 - 0.99)$$

) Common collector configuration:

In CC configuration "collector" is the common terminal b/w input and output.

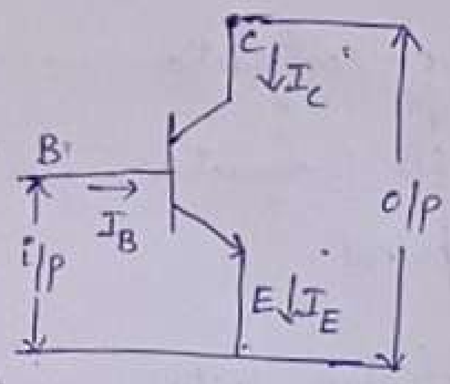


Current amplification factor,

$$\gamma = \frac{\text{o/p Current}}{\text{i/p Current}} = \frac{I_E}{I_B}$$

3) Common emitter configuration:

In CE configuration, "emitter" is the common terminal b/w input and output.



Current amplification factor, $\beta = \frac{\text{o/p Current}}{\text{i/p Current}} = \frac{I_C}{I_B}$

* CE (common emitter) configuration is used frequently for amplification purpose.

Relation b/w α and β

α = Current gain in CB configuration, $\frac{I_C}{I_E}$

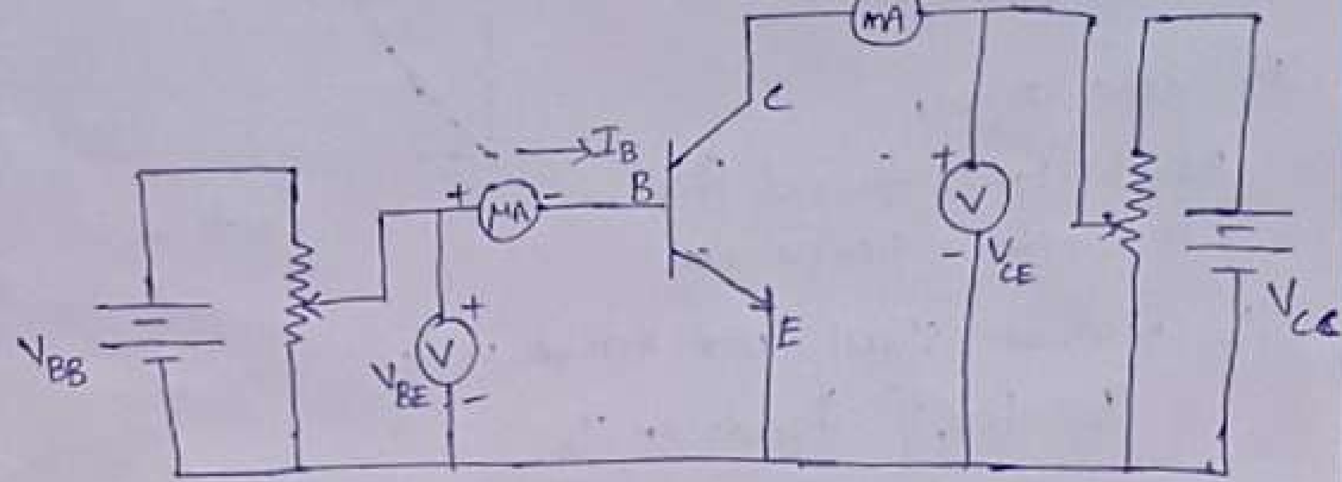
β = " " " CE " , $\frac{I_C}{I_B}$

For any type of transistor, $I_E = I_C + I_B$

divide above eq by I_C, we get

$$\frac{I_E}{I_C} = 1 + \frac{I_B}{I_C} \Rightarrow \frac{1}{\alpha} = 1 + \frac{1}{\beta} \Rightarrow \boxed{\alpha = \frac{\beta}{1+\beta}} \Rightarrow \boxed{\beta = \frac{\alpha}{1-\alpha}}$$

Transistor as an Amplifier :-



i/p Current = I_B o/p Current = I_C

i/p Voltage = V_{BE} o/p Voltage = V_{CE}

input characterstics :-

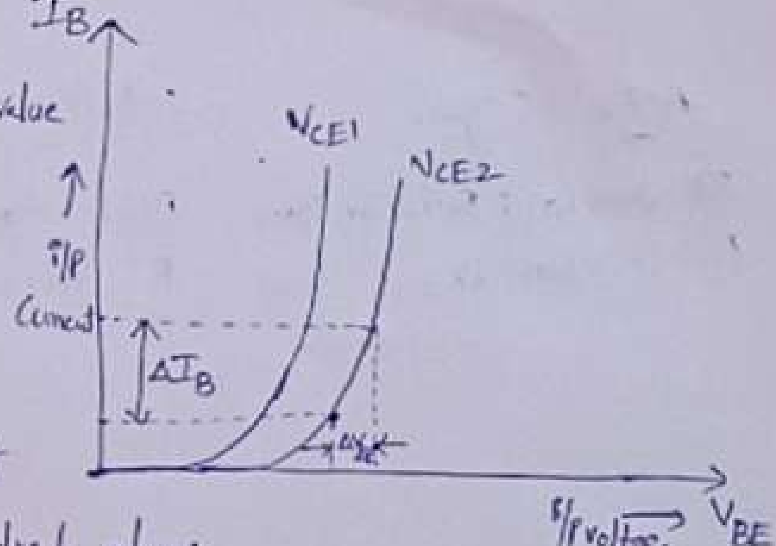
It shows the relation b/w input voltage and input current

The i/p characterstics of CE configuration is same as P-N junction diode V-I characterstics

O/p votage V_{CB} kept at particular value change the i/p voltage V_{BE} then input Current I_B varies

i/p resistance, $r_i = \left.\frac{\Delta V_{BE}}{\Delta I_B}\right|_{V_{CE}\text{ Constant}}$

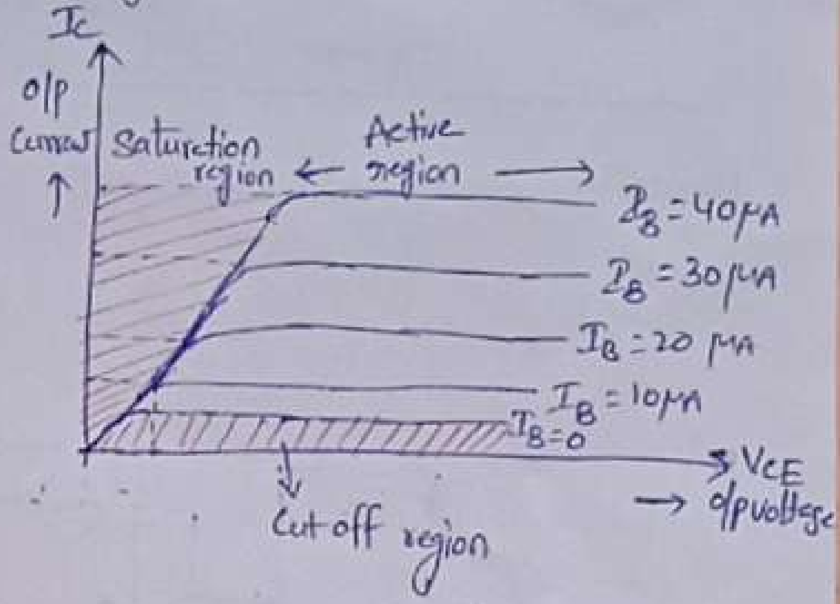
r_i is of the order of a few hundred ohms.



Output Characterstics:

It Shows the relation b/w o/p voltage and o/p Current

Kept i/p Current I_B as Constant and Vary V_{CE} from zero then I_C increased.



In Active region,

BE Junction : forward Bais
CB Junction : Reverse Bais

I_C increases Slightly with increase in V_{CE}

I_C largely depends on I_B

$$\boxed{I_C = \beta I_B}$$

Transistor acts as an Amplifier in active region.

Amplifier :-

An amplifier is an electronic device that increases the voltage, current (or) power of a Signal
(or) It increases the Strength of a Signal.

Active region	Cutoff region	Saturation region
BE Junction : Forward Bias	BE junction: Reverse	BE junction : Forward Bias
BC Junction : Reverse Bias	BC junction. Reverse	BC Junction : Forward Bias

4.2.9 *Applications of DC Motors*

DC shunt motors are used where the speed has to remain nearly constant with load and where a high starting torque is not required. Thus shunt motors may be used for driving centrifugal pumps and light machine tools, wood working machines, lathe etc.,

Series motors are used where the load is directly attached to the shaft or through a gear arrangement and where there is no danger of the load being "thrown off". Series motors are ideal for use in electric trains, where the self-weight of the train acts as load and for cranes, hoists, fans, blowers, conveyers, lifts etc. where the starting torque requirement is high.

Compound motors are used for driving heavy machine tools for intermittent load shears, punching machines etc.,

4.3.9 *Applications of Transformer*

Transformers are used in

i) Electrical power engineering for transmission and distribution

ii) As an instrument transformer for measuring current (C.T) and measuring voltage (P.T)

iii)As a step down and step up transformer to get reduced or increased output voltage

iv) Radio and TV circuits, telephone circuits, control and instrumentation circuits

v) Furnaces and welding transformer